RISK FACTORS OF WATER-BORNE DISEASES
With A
PROVISION OF WATER

Water Governance and Capacity Building Support
WGCB Jacobabad

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RISK FACTORS OF WATER-BORNE DISEASES With A PROVISION OF WATER

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1. BACKGROUND

USAID has approved 2 years Water Governance & Capacity Building Program that will serve 275,000 population of Jacobabad city through safely managed water supply services and capacity building of local government department and Municipal Committee Jacobabad.

Under an Activity Agreement signed with the Government of Sindh, USAID is aiding and investment under Sindh Municipal Services Program, to improve the water and sanitation service delivery through the construction of infrastructure facilities in the city of Jacobabad. The Government of Sindh has entrusted Jacobabad Municipality through an official notification to operate and manage the USAID funded water project. Multiple assessments reveal the following facts about the local government institutions at Jacobabad.

- Unclear institutional roles, lack of planning capacity and technical expertise to operate water supply system at par with national standards are one of the reasons for not developing a viable and safe water supply systems in the area.
- The local governments have not made any commendable investment in the construction of technically sound water supply schemes to carry out maintenance of old schemes.
- The Jacobabad Municipality employs eight hundred and sixty-four (864) staff – most of whom are sanitation workers, and there is a shortage of technical staff.
- MC staff at Jacobabad have not received in-service training in the last 7 years and to bring the organization up to speed, there is a need of a focused capacity building and training on financial management, including planning for new development schemes, management information systems, communication, monitoring and evaluation, and citizen involvement.
- The staff of Municipal Committee Jacobabad talks about a repeated theme of lack of coordination. On further probing it was revealed that official communication between the Provincial Government and Municipality has several shortcomings, this often results in an irregular and ineffective flow of information.

The municipality with all its challenges and shortcomings has the legal responsibility for the provision of services. The transition period in local government has weakened the already withered capacity, and hence there is a dire need for capacity building of the Municipality's staff. HANDS with the support of USAID is implementing Community Mobilization for Water Governance, Health, and Hygiene, In Jacobabad City, Sindh Pakistan project.

The overall objective of the CMHH project is to mobilize community support and participation in the Municipal Services Program (MSP), complementing an increase in transparency and accountability for water and sewerage services with improved community and household hygiene behaviors in Jacobabad. City, through:

1. Increased transparency and accountability for water and sewerage services
2. Improved health and hygiene behaviors,
3. Informal water vendor action plan and
4. Targeted Technical Assistance to Utility and MSP - PMU.

The proposed project will consolidate and continue behavior change activities through a comprehensive behavior change campaign, in a revised form to support the adoption of improved WASH-related behaviors. The project will facilitate Municipal Committee Jacobabad in creating

a social engagement unit and facilitation in developing TORs and SOPs for staff and mentor its staff in the initial phase of operations. The Sustainable Development Goals have set some tough and formidable targets for the water sector as under;

- 6.1 achieve universal and equitable access to safe and affordable drinking water for all
- 6.2 achieve access to adequate and equitable sanitation and hygiene for all 6.4 substantially increase water-use efficiency across all sectors.

1.1 Water and Human Health

The objective of this assignment was

To enlist the risk factors of water-borne diseases Water is essential for life and is very important to use safe drinking water to prevent water-related diseases. Typically water-related diseases are categorized into four classes:

(1) Water-borne (caused by bacteria, viruses, and protozoans)
(2) Water-based (caused by parasitic worms, mosquitoes, etc.)
(3) Water-washed (caused by chemicals, pesticides, etc.)
(4) And water-related insect vectors (caused by infections)

Waterborne diseases are mainly caused by pathogenic microorganisms which are mostly transmitted through the ingestion of contaminated freshwater. The wealthier countries have been eliminated from the burden of waterborne diseases in today's world but the developing countries are still suffering from this hard issue[1]. According to WHO about 1.1 billion people in the world drink impure water while UNICEF reported that approximately 800 million people living in African and Asian countries do not have access to pure and safe drinking water. The most important concern about human life is the quality of water; fecal pollution in drinking water is the central cause of waterborne diseases, which can ultimately destroy the entire population.

In 1980, the United Nations inaugurated the International Water Supply and Sanitation Decade (1981-1990), with the goal of worldwide availability and use of readily accessible, safe, reliable, and adequate community water supplies and sanitation by the year 1990. The "Decade" was stimulated by the gross inadequacy of these basic human needs in the developing world, where perhaps 1.5 billion people lack reasonable access to safe water. The situation is even bleaker for sanitation. According to statistics compiled by the World Health Organization (WHO), the rural areas of Africa, Asia, and Latin America, in particular, are poorly served only one in five residents have access to safe water.

Also during 1980, the World Health Organization (WHO) directing authority, composed of member country representatives) adopted the goal of "Health for All by the Year 2000," with

[1] *WHO (World Health Organization), "Emerging issues in water and infectious disease. Geneva: World Health Organization (WHO)," 2003.*

increased emphasis to be placed on the goal of "primary health care." Water supply and sanitation are by WHO (and UNICEF) definition, a component of primary health care[2].

Water is an absolute necessity for life. However, water can also be a carrier of suffering and death. Conversely, the ready availability of water makes possible a hygienic environment that prevents or limits the spread of many human and animal diseases. In the United States, with occasional exceptions, the endemic and epidemic waterborne disease has been of minor consequence in the overall national health status for over half a century. It is often forgotten that during the 19th-century cholera pandemics, thousands died of waterborne cholera in such American cities as New York, New Orleans, and St. Louis. Much of our understanding of the epidemiology of typhoid fever is due to the pioneering studies by William T. Sedgewick of water supplies in New England in the 1890o and by Wade Hampton Frost of Ohio River Valley communities during the first decades of the 20th century. At the turn of the three-century, diarrheal diseases killed small children in the United States at rates comparable to those of today in the developing world, where, in many countries, one child in four never reaches his fifth birthday.

1.1.1 Water-related Diseases

The World Health Organization estimates that 500 million diarrheal episodes occur each year in children under five in Asia, Africa, and Latin America. Three to four percent of these end in death (WHO, 1979; also see Rohde and Northrup, 1976; Barker, 1975; and Gwatkin, 1980). These illnesses are the result of poverty, ignorance, malnutrition, and poor environmental sanitation, particularly inadequate water supply and excreta disposal.

Table 1: Estimated Proportion of Preventable Water-Related Disease[3]

Waterborne Diseases	**% Reduction by the safe water supply**
Guinea Worm	100
Typhoid	80
Urinary Schistosomiasis	100
Leptospirosis	80
Trypanosomiasis, Gambiense	80
Scabies	80
Yaws	70
Inflammatory Eye Disease	70
Schistosomiasis, unspecified	60
Trachoma	60
Bacillary Dysentery	50
Amebiasis	50
Dysentery, unspecified	50
Tinea	50
Gastroenteritis, 4 weeks to 2 year	50

[2] *WHO, 1978a; UNICEF-WHO Joint Committee, 1979.*
[3] *National Academy of Sciences. Drinking Water and Health. Vol. 3. Pp. I- 24. 1980.*

Gastroenteritis, over 2 year	50
Skin and Subcutaneous Infections	50
Diarrhea of the Newborn	50
Paratyphoid and other Salmonella	40
Lousebome Typhus	40
Intestinal Schistosomiasis	40
Ascariasis	40
Louseborne relapsing fever	40
Otitis Externa	40
Classic skin (leg) Ulcer	40
Trypanosomiasis, unspecified	10
Dental caries	10
Overall	52

Water contact, with skin penetration by pathogenic agents of disease, is important in the tropics. Because many occupations require the use of water--irrigation farmers; fishermen; women with no alternative to surface waters for washing clothes, utensils, and children; persons performing religious ablutions; children swimming or washing animals in hot climates; and others--much exposure cannot be readily prevented. Some of these diseases are major health problems in many countries, e.g., schistosomiasis. Also vectors of many diseases live part or all of their lives in a water environment. Mosquitoes and certain fly and snail species are examples.

These diseases malaria, onchocerciasis, schistosomiasis, etc. are, of course, important. However, because (1) our major focus is on water supply interventions and (2) a huge literature on these diseases is available, coverage here will be shortened. Sanitation, especially disposal of human excreta (feces, urine, and vomitus), is closely allied with water supplies; however, an extensive treatise on sanitation/health relationships prepared at the London School of Tropical Medicine and Hygiene for the World Bank has been published (Feacham *etal.,* 1980); therefore, coverage is limited to one section which guides program design. One other omission should be noted. Many respiratory diseases could be termed "waterborne" in that they may be transmitted via droplets and aerosols composed largely of water. These are not affected by the provision of water supplies. Remarks here are confined to health hazards, which might arise from certain methods of wastewater treatment.

1.2 Historical Development of Our Understanding of Water Supply and Disease

1.2.1 Introduction

This discussion of the relationship between water supply and sanitation and disease can be conveniently divided into (1) the wisdom of the ancients, (2) natural experiments, (3) sanitary revolution, (4) biological plausibility, (5) studies of epidemic disease, (6) Studies of endemic disease. All these categories of course overlap.

1.2.2 Wisdom of the Ancients

Numerous savants of the ancient world related water and health. For example,

Hippocrates was remarkably accurate in his observations on goiter and water supply[4]. Several ancient religious codes endorsed hygienic practices, which even today remain appropriate.

1.2.3 Natural Experiments

The industrial revolution and the rise of large urban populations requiring public water supplies during the 19th century were often accompanied by massive epidemics, many of which could be considered natural experiments. The classic epidemiological study by Dr. John Snow of an 1854 outbreak of cholera in London was a pioneering effort of scientific understanding. Over 700 deaths from cholera occurred in St. James Parish in 17 weeks. Snow's detailed study showed that most of the victims had used water from the Broad Street pump and further, that leaky sewerage that passed adjacent to the well for pump drained the house at No. 40 Broad Street, site of the original cholera case. Remarkably, Snow's study pre-dated Pasteur'germ theory of disease by one decade and Koch's identification of the causative organism, Cholera vibrio, by three decades. The first cholera pandemic (1817–1824), also known as the first Asiatic cholera pandemic or Asiatic cholera, began near the city of Calcutta and spread throughout South and Southeast Asia to the Middle East, eastern Africa and the Mediterranean coast [5] . Another big epidemic of cholera outbreak began in the rural Center department of Haiti, about 100 kilometers (62 mi) north of the capital, Port-au-Prince. By the first 10 weeks of the epidemic, cholera spread to all of Haiti's 10 departments or provinces. It had killed 4,672 people by March 2011 and hospitalized thousands more[6]. This epidemic has more resembled in countries with non-endemic (or epidemic thereafter) cholera, that is, experiencing periodic and sudden outbreaks of cholera include Pakistan (2008) and Congo (2008), and most recently Haiti (2010).

A serious epidemic of cholera occurred in Hamburg in 18920 when unfiltered water from the River Elbe was supplied to the city. In that outbreak Koch succeeded in isolating *Cholera vibrio* from the river water. Hamburg and the contiguous town of Altona both drew water from the River Elbe and discharged sewage to it at some points. The water of Altona-bring downstream from Hamburg-was initially the more polluted, but Altona filtered its water through slow sand filters and Hamburg did not. In the course of a few weeks 18,000 persons in Hamburg were attacked by the disease and 8000 died. The death rate from cholera in Hamburg was 13.4 per 1000 of the population; Altona suffered much less, the death rate is 2.3. Almost all of the cases that occurred in Altona had drunk Hamburg water. In Hamburg it there was a block of tenements housing some 400 persons; these tenements were supplied with Altona water and the inhabitants escaped untouched.

1.2.4 Sanitary Revolution

The Indus Valley Civilization in Asia shows early evidence of public water supply and sanitation. The system the Indus developed and managed included some advanced features. A typical example is the Indus city of Lothal (c. 2350 BCE). The first sanitation facility was the sump or cesspit that appeared in Babylon around 4000 B.C. A simple digging in the ground to concentrate the excreta that could soon be found in other cities of the empire and rural areas. The water supply already existed in cities at that time, but it was not until 3000 B.C., in the city of Mohenjo-Daro, in the

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[4] *McJunkin FE. Water and Human Health 1982.*

[5] *https://en.wikipedia.org/wiki/1817–1824_cholera_pandemic*

[6] *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3381400/*

Indo valley (in modern-day Pakistan) that we find the first buildings with latrines connected to a sewage system. The citizens washed down their latrines with water and the sewage system collected this wastewater and took it to the sump or the Indo River. The problem had grown and became more complex and we started polluting the water flows systematically[7].

Diseases associated with poor sanitation and crowded environments decreased in numbers even without planned interventions, curative medicine, or immunizations. Lifespans increased. (McKeon and Record, 1955; Wain, 1970). It can be argued that many LDCs are repeating or on the verge of repeating western history in this regard.

The following examples ate illustratively. Cvjetanovic (1975) shows the similarity of decline in enteric disease in the United States and 51 developing countries if the time scale is adjusted. (See Figure 1-2.)

A study (Johnson, 1916) of the fall (65 percent), in typhoid mortality in 20 American cities following the introduction of water supply filtration bears a remarkable similarity to the fall in typhoid mortality (63.6 percent), in 14 Indian towns following the introduction of water purification a half-century later than in the U.S. cities (Zaheer, *et al.*, 1962). In Punjab some 15 years ago, the infant death rate from diarrhea in the second six months of life was 56 per 1000. A half-century earlier in New York City, the rate was precisely the same (Rohde and Northrup, 1976).

1.2.5 Biological Plausibility

Although the London cholera studies by John Snow are considered epidemiological classics (and appear as examples in most standard epidemiological textbooks), they had little impact on then-current practices. Only after Pasteur, Eberth, Koch, et al., identified the causative pathogenic micro-organisms did full acceptance come-aided immensely by Koch's "postulates" for confirming that a bacterium was indeed the agent of a specific disease. This of course led to the identification of the "portal of entry" of the microorganisms to the human body. Many, of course, were through the mouth to the gastroenteric tract, carried by water or food. It could be conclusively demonstrated for such diseases as cholera and typhoid that fecal-oral routes were predominant in the transmission of the disease. Thus any interventions, which broke the decay, the fecal-oral cycle could be effective: keep feces out of the water, milk, and food and/or destroy or remove pathogens in water, food, or soil or on hands through the cook, or on hands through treatment (e.g., disinfection), cooking, or cleansing.

1.4 Water and water-borne diseases in Pakistan

Due to an alarming increase in population and rapid industrialization, drinking water quality is being deteriorated day by day in Pakistan. This review sums up the outcomes of various research studies conducted for the drinking water quality status of different areas of Pakistan by taking into account the physicochemical properties of drinking water as well as the presence of various pathogenic microorganisms. About 20% of the whole population of Pakistan has access to safe drinking water. The remaining 80% of the population is forced to use unsafe drinking water due to the scarcity of safe and healthy drinking water sources. The primary source of contamination is

[7] *https://en.wikipedia.org/wiki/History_of_water_supply_and_sanitation*

sewerage (fecal) which is extensively discharged into drinking water system supplies. The secondary source of pollution is the disposal of toxic chemicals from industrial effluents, pesticides, and fertilizers from agriculture sources into the water bodies. Anthropogenic activities cause waterborne diseases that constitute about 80% of all diseases and are responsible for 33% of deaths. This review highlights the drinking water quality, contamination sources, sanitation situation, and the effects of unsafe drinking water on humans. There is an immediate need to take protective measures and treatment technologies to overcome the unhygienic condition of drinking water supplies in different areas of Pakistan.

1.4.1 Impact of clean drinking water and sanitation on water-borne diseases in Pakistan

Water is an essential need of human beings. Every person on this planet requires at least 20 to 50 liters of safe water in a day for drinking, cooking, and other purposes. According to the United Nations (UN) the basic human right is to universal access to safe water, and an essential step towards better living standards all over the world. According to the government of Pakistan Economic survey (2008) In Pakistan, it revealed that nearly 50 million people are deprived of safe drinking water. In this research it is intended to produce trends of Sanitation and safe drinking water situation in Pakistan. This study also looks deep into the relationship of water-borne diseases with the background information of the respondents. Which is itself is a contribution of my work on water-borne diseases. Secondary Data from Pakistan Demographic Health Survey (PDHS) and Multiple Indicator Cluster Survey (MICS) has been used. To see the individual impact of environmental, social, and demographic characteristics to influence diarrhea separate equations were executed. Presenting the pathways of communicable diseases, has developed from two model i.e. model of Exposures and health outcomes are difficult by unified factors studied by Montgomery et al., (2007) and model of transmission pathways of fecal-oral diseases studied. Results of the study conclude that Post-neonatal i.e. greater than 28 days from birth deaths have a significant proportion caused due to diarrheal morbidity. There are almost 7 postnatal deaths (per thousand) that happen due to childhood morbidity of diarrhea and almost the same is for the children who are under five years old. Urban zones showed a high prevalence of diarrhea among children and rural areas brought high rates of childhood diarrhea. Incidences of diarrhea are more for households with not-improved toilet facilities as compared to those with improved toilet facilities. Incidence of childhood diarrhea emerges more for children belonging to households with pit latrine with a slab. Educated mothers are hypothesized to be beneficial for less prevalence of diarrhea. In this regard, our investigation shows that, educated mothers are highly influential. In the end Policy Recommendations has been given which are rational to be incorporated in policies for Policy Makers.

1.5 Water and water-borne diseases in Jacobabad

In Pakistan, contaminated water by bacteria is the main source of waterborne diseases but the situation of Jacobabad is more dreadful, the increasing population of the city is facing problems like bad road infrastructure, poor water storage, the squeezed structure of sanitation and terrible solid waste management[8]. The health facilities in the city are inadequate and people are suffering

[8] *UN-Habitat, "Willingness to pay for WASH" contingent valuation method study in Jacobabad, 2015.* [9] *IMMAP, "Pakistan emergency situational analysis," A profile of District Jacobabad, 2014.*

from so many diseases, especially water-related diseases like Hepatitis A & E, Diarrhea, Malaria, Typhoid, Dysentery, Skin diseases, and Eye infections[9].

1.6 Data on diarrheal diseases reported at Civil Hospital Jacobabad

The City of Jacobabad has a high prevalence of childhood diarrhea. The referral point for the patients in the city is Civil Hospital Jacobabad. The following data shows the childhood diarrhea cases reported at health facilities of Jacobabad from June 2016June 2017;

Diarrhea cases reported by Civil Hospital in 2016	**19.8% of all OPD**
Percentage of children under age 5 with diarrhea in the last 2 weeks for whom advice or treatment was sought from a health facility or provider	69.2
Percentage of children under age 5 with diarrhea in the last 2 weeks for who receive ORS and zinc	11.6
Percentage of children under age 5 with diarrhea in the last 2 weeks given treatment by oral rehydration therapy & continued feeding	41.0

2. METHODOLOGY

We have adopted a mix methods approach for this formative research using the following methods;

i. LITERATURE REVIEW:

Reviewed relevant literature to develop this report based on both national and international findings. **ii. DOCUMENT REVIEW:**

Local health reports like district health information reports, DHIS surveys, hospital, and LHW data will be reviewed to assess the burden of waterborne diseases among children living in Jacobabad. Information will be compared with other published reports like; MICS Survey, PDHS Survey, and WHO data **iii. OBSERVATION AND FIELD VISIT:**

iv. ANALYSIS OF COLLECTED DATA:

Descriptive statistics and content analysis were employed for data analysis. Descriptive statistics such as frequencies, percentages, and means were used to obtain the variability and central tendencies of variables. Content analysis was used to analyze the qualitative data obtained from respondents during the entry/briefing meeting, field visits, the exit/debriefing meeting, and discussion with key informants. This entailed transcribing all response notes and categorizing the obtained information into main themes and issues. The findings and issues found out during this study are presented in the next section.

3. Interventions to Control Waterborne Diseases:

Interventions for controlling waterborne transmission include the following:

Interventions needed to control Water-borne diseases			
Water Supply	**Sanitary Excreta Disposal**	**Health Education**	**Current practices adopted by MC Jacobabad**
Selection of uncontaminated sources, e.g., wells from deep aquifers.	(1) Protection of water supplies.	(1) Personal and community hygiene.	Water is being pumped from a source to the filter plant, where it is cleaned by physicchemical measures to be supplied to the citizens in the city.
Treatment of raw water, especially chlorination,	Protection of the environment.	Protection of the environment.	The facility of wastewater treatment is not provided by MC.
Replacement of contaminated water supplies by more convenient, reliable, safe supplies.	Support for water supply and excreta control activities.	Support for water supply and excreta control activities.	Awareness on WASH is the active part of WG conducted regularly by the teams
Protection of watersheds.	Destruction, removal, isolation, or dilution of fecal wastes.		School Health program is actively providing WASH
Water quality surveillance.			

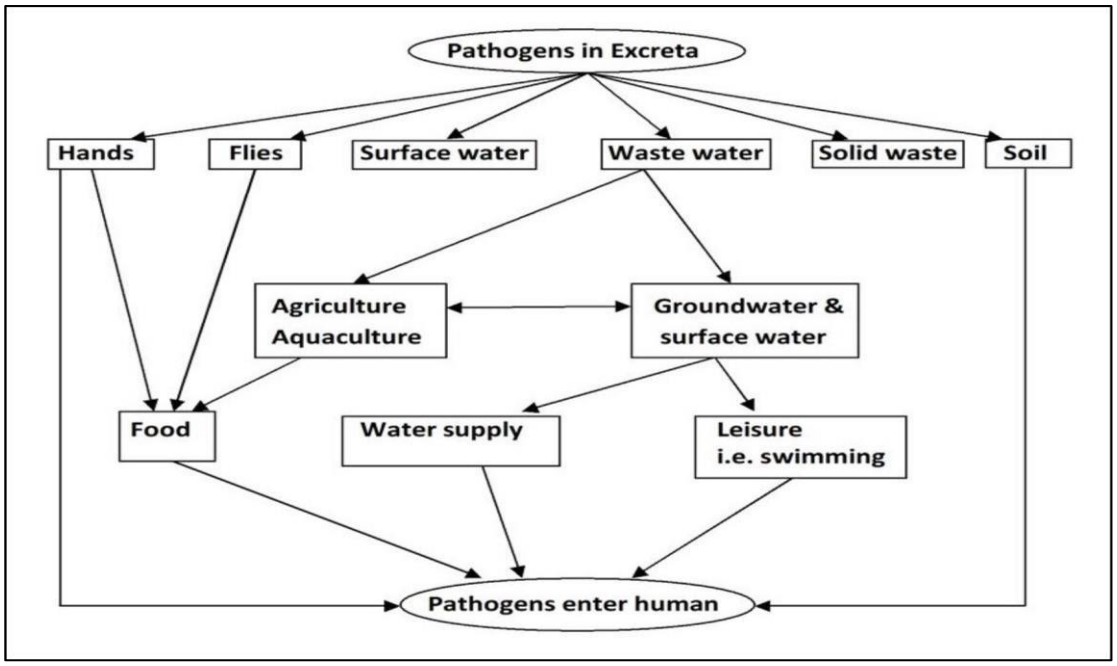
3.1 Transmission of Water-Related Diseases

***Mode of transmission of the pathogen causing waterborne diseases*:**

The most common mode of transmission is via a fecal-oral route whereby contaminated water is ingested. There is a possibility of food contamination as human beings depend on agriculture or aquaculture in quest of food which could be polluted by wastewater with excreta. The use of contaminated water in the household and even swimming in it would be the possible cause of

waterborne diseases. Figure 1 showed how organisms found in the fecal matter can be transmitted to humans**.**

Figure 1: Mechanism of transmission of waterborne pathogens



Source: https://www.eolss.net/Sample-Chapters/C03/E2-20A-01-04.pdf

For convenience the more important water and excreta-related diseases are categorized in terms of appropriate interventions:

3.1.1 Waterborne-Microbiological Diseases

These are diseases in which the pathogens are in the water and, when ingested at a sufficient dose, infect the drinker. The majority of these pathogens reach the water through contamination with human excreta and ultimately enters the body through the mouth, hence, the term "fecal-oral transmission." Many fecal-oral diseases are readily transmitted through other means, for example, fecally contaminated food or hand to mouth. Thus, not all typhoid, for example, is waterborne. The more important of these diseases include amebic dysentery, shigellosis, cholera, diarrheas (non-specific etiology), *E.coli* diarrheas, viral diarrheas, hepatitis A virus, and typhoid fever.

3.1.2 Waterborne- Chemical Diseases

These are illnesses associated with the ingestion of water containing toxic substances in harmful concentrations. These may be of natural origin or man-made. They are generally locality specific. Interventions include their removal (generally pensive) or selection of alternate sources. On a global basis, these are not major problems in nonindustrial countries and are generally of lower priority than microbiological diseases.

3.1.3 Water Hygiene Diseases

These are diseases whose incidence, prevalence, or severity can be reduced by using water to improve personal and domestic hygiene. These include many of the fecaloral transmission diseases also listed as waterborne. Most of these diseases may also be transmitted by food, hand-to-mouth contact, and numerous other means. Some of them, e.g., shigellosis, is possibly more predominantly transmitted in these ways than through drinking water. Other hygienic diseases include those of the skin, e.g., tinea, and eyes, e.g., trachoma. Some hygienic skin diseases are associated with insect infestations; for example, mites cause scabies, pediculosis by lice. Lice also can transmit other diseases; for example, louseborne typhus. Sufficient water must be available for hand washing, bathing, laundering, and cleaning of cooking and eating utensils. This quantity is needed in addition to that used for drinking.

3.1.4 Water Contact Diseases

These are diseases transmitted by skin contact with pathogen-infested water. The most important of these diseases is schistosomiasis (bilharzia). Schistosome eggs in human excreta hatch in reaching the water. The resulting larvae must invade suitable snail hosts or perish. Following a multiplication process within the snail, the freeswimming schistosome larvae (cercariae) escape from the snail and find and invade man by penetrating his immersed or wetted skin. This important tropical disease infects over 200 million people, and its prevalence is probably increasing. Current control methods, primary drugs for those infected, and chemical control (mofluscicide) of snails have had limited success. Both of these methods required, periodic repetition.

3.1.5 Water Vector Habitat Diseases

These are diseases that depend during part of their life cycle on animal vectors that live all or part of their lives in or adjacent to a water habitat. The archetypes are schistosomiasis (associated with snails), malaria (associated with mosquitoes), and onchocerciasis (associated with aquatic flies). The relationship of schistosomiasis to the water supply was previously described**.**

3.1.6 Excreta Disposal Diseases

These are diseases whose transmission may be effectively interrupted by sanitary disposal of human feces and urine. They include most of the fecal-oral diseases previously described un-der waterborne diseases; (theoretically) the snail-vectored parasitic diseases; and the following helminthic infections of the intestinal tract: ascariasis (roundworm), hookworms, Strongyloides (threadworm), trichuriasis (whipworm), and several others of lesser importance. Ascariasis and trichuriasis are fecal-oral route diseases, primarily by hand to mouth and by ingestion of contaminated soil. The distributions of parasites were Giardia lamblia 50% and Entamoeba histolytica 48.86%. Statistically none of the socio-demographic variables were associated except education and age group[9]. A total of 1041 stool samples were examined from January 2006 to December 2008 using direct smear and concentration methods. One hundred and fifteen (11.04%) participants were found infected with one or more than one intestinal protozoans. Forty-one (35.6%) of the participants were infected with a single parasite and seventy-four (64.3%) with

[9] *Siddiqui MI. Prevalence of Parasitic Infections in a Rural Area of Karachi, Pakistan. Pak J Med Ass 2002.*

multiple infections. *Entamoeba histolytica* 30.5% (n=77/252), *Giardia lamblia* 15.0% (n=38/252), *Ascaris lumbricoides* 17% (n=43/252), *Trichuris trichura* 11.1% (n=28/252), *Enterobius vermicularis* 9.52 (n=24/252), *Ancylostoma duodenale* 3.96% (n=10/252), *Taenia saginata* 9.52% (n=25/252) and *Hymenolepis nana* 2.77% (n=7/252) were detected in order of their prevalence. The adults were found marginally more parasitized than children ($P<0.05$)[10].

3.1.7 Waterborne Microbiological Diseases: Fecal-Oral Transmission

Many of these diseases are transmitted through "fecal-oral" or "anus to mouth" pathways. Sources of drinking water are contaminated by human excreta (or for a few "zoonotic" diseases by animal excreta) avoided by someone with an infection. That person may be someone ill or a "carrier." A carrier harbors the disease organisms within his body without manifest symptoms. Carriers are often more important in transmission than those persons ill.

3.2 Risk factors of water-borne diseases

Unsafe drinking water is the main cause of developing these water-borne diseases, detail can be seen in table 2.

Table 2: List of water-borne diseases and risk factors

Waterborne Diseases	Fecal-Oral Pathways/risk factors
Amoebic Dysentery (Amebiasis)	Epidemics mainly by water, endemic spread by water, food, and hand-to-mouth contact. Resistant to chlorination
Ascariasis (Giant roundworm)	Usually soil-borne but also waterborne on occasion.
Bacillary Dysentery (Shigellosis)	Also by food and milk, flies, and direct contact.
Balantidial Dysentery (Balantidiasis)	Epidemics mainly by water. Endemic spread by water, food, and flies.
Campylobacter enteritis	Only recently recognized as an important cause of pediatric diarrhea.
Cholera (Classical and El Tor)	Classical waterborne disease, now pandemic. High fatality in untreated cases.
Coccidiosis	Rare, mild
Diarrheas (Including Weanling Diarrheas and Gastroenteritis)	Clinical syndromes of varied etiology, generally unidentified, especially in LDCs, Were frequently listed as the leading causes of death.
	Primarily fecal-oral.

[10] *Khan W. Prevalence of Potentially Important Intestinal Pathogenic Protozoan Parasitic Infections in Different Occupational Groups of Swat, Pakistan. Pak J Zoology 2018.*

E. coli (Enteroinvasive, Enteropathogenic, & Enterotoxin)	Growing understanding of the role in diarrhea of children and travelers.
Enteric viruses	Many are pathogenic. The role not well understood. May cause diseases of the central nervous system.
Giardiasis	Receiving increasing attention. Resistant to chlorination.
Hepatitis A. virus	Several transmission routes including fecal-oral. 30,000 cases in 1955-56 New Delhi outbreaks.
Hookworm and strongyloidiasis	Normally larvae in soil penetrate bare skin, usually of the foot. It may also be transmitted in water.
Hydatid Disease (Echinococcosis)	Transmitted by the ingestion of infective eggs in water and food contaminated by dog feces.
Non-cholera Vibrios	Increasingly recognized as a cause of diarrheal disease.
Norwalk virus infection	A significant cause of diarrhea.
Paratyphoid Fever	Direct or indirect contact with feces or urine of patient or carrier. The indirect spread usually through food, esp. milk and shellfish, and, occasionally, through water supplies.
Poliomyelitis	The waterborne transmission has been observed but is rare.
Rotavirus infection	Newly identified agent of infantile diarrhea. Probably fecal-oral.
Salmonellosis	An acute gastroenteric, infectious disease usually spread by fecally contaminated food. Waterborne epidemics are known, e.g., 15,000 cases in Riverside, California, in 1966 from contamination of a public water supply.
Schistosomiasis	Waterborne transmission occurs, but skin penetration of the major portal of entry.
Travelers' Diarrhea	Often due to one of many serotypes of E. coli bacteria.

Trichuriasis (Whipworm)	Usually soil-borne but also waterborne on occasion.
Typhoid Fever	Spread through contaminated water and food. Urinary carriers frequent in S. hematobium areas.
Yersinosis	Worldwide but rarely recognized.
Anthrax	Transmission by drinking water dubious although cited by various authors.
Brucellosis	Documented but probably very rare.
Cysticercosis (Bladder Worms)	Ingestion of eggs in food or water. Larval infection with T. solinin. Other transmission routes. A serious disease.
Gongylonemiasis (Scutate Threadworm)	Rare. Ingestion of water containing larvae from disintegrated insect hosts.

Guinea Worm Disease (Dracontiasis)	Complex transmission route with intermediate vector (Cyclops). Not fecal-oral. Found only in LDCs and transmitted only by water.
Leeches (Hirudiniasis)	Infestation by young aquatic leeches.
Leptospirosis (Well's Disease)	A zoonosis. Transmission more often by skin contact with contaminated water.
Liver Fluke Disease (Cionorchiasis, et at.)	Occasional ingestion ok drinking water containing metacercariae from decomposed fish. Most infections from eating raw fish.
Melioidosis	Rare. Southeast Asia.
Sparganosis	Ingestion of water containing Cyclops infected with certain cestode larvae. Other transmission routes.
Tularemia	Ingestion of untreated water from watersheds when infection prevails among wild animals, esp. rabbits, is one of several transmission mechanisms.
Toxicoses	Chemicals in water like metals
Fluorosis	Damage to teeth and bones resulting from long-term ingestion of high concentrations of naturally occurring fluorides.
Endemic Goiter	Iodine-deficient water or water containing goitrogens.

3.2.1 Diarrheal diseases

Diarrhea of abrupt onset occurring in otherwise healthy persons is most often related to an infectious process. A variety of accompanying symptoms is often observed, including fever, headache, anorexia, vomiting, malaise, and myalgia, but they cannot always be used to distinguish the causative agent with certainty. Only during the past decade has medical science been able to identify with reasonable certainty the pathogens of many of the more important diarrheal diseases, e.g., rotaviruses. The role of *Escherichia coli* has turned out to be much more important than originally believed. Campylobacter enteritis, yersiniosis, and Norwalk-type viral diarrhea similarly have received increased recognition.

3.2.1.1 Risk factors of Diarrhoea

Following are the main risk factors caused by different organisms to develop these conditions

Infectious agent

- Acute infectious non-specific gastroenteritis (AING) o Amebiasis (amebic dysentery) o Balantidiasis (balantidial dysentery) o Campylobacter enteritis Capillariasis, o Intestinal Cholera
- Clonorchiasis (Chinese liver fluke) o Coccidiosis
- Diphyllobothriasis (fish tapeworm)
- *Echerichiacoli* diarrhea (Enteroinvasive, enteropathogenic, euiterotoxigenic) o Fasciolopsiasis
- Giardiasis Guinea-worm (dracontiasis) disease

- Leishmaniasis o Malaria,
- Pernicious Non-cholera vibrio disease o Opisthorchchiasis o Paratyphoid fever
- Rotavirus gastroenteritis o Salmonellosis o Schistosomiasis o Shigellosis o Strongyloidiasis o Trichinosis o Tuberculosis o Trichuriasis o Tularemia
- Typhoid fever (constipation more common than diarrhea) o Viral Diarrhea (Norwalk type) o Yersiniosis

Non-infectious agents

- Amyloidosis o Cathartics Crohn's disease o Diverticulitis o Drugs
- Drugs Endocrine disorders o Erratic colon
- Malabsorption disorders (e.g., sprue) o Poisoning

3.2.2 Cholera

Cholera is an acute illness, which results from colonization of the small intestine by Vibrio cholera, the cholera bacillus. The disease is characterized by its epidemic occurrence and the production in the more severe cases of massive diarrhea with rapid depletion of extracellular fluid and electrolytes.

3.2.2.1 Risk factors of Cholera

Vibrio cholera produces a protein enterotoxin, which appears to be responsible for all known pathophysiological processes in cholera. The incubation period generally from 6to 48 hours. This is followed by the abrupt onset of watery, generally painless s Diarrhoea.

The majority of major epidemics have been waterborne, but direct contamination of food by infected feces probably contributes to spread during major outbreaks. Poor sanitation appears to be primarily responsible for the continuing presence of cholera, but host factors, such as relative or absolute achlorhydria (absence of hydrochloric aid), also play an important role in the susceptibility of the individual to infection. In endemic areas, cholera is predominantly a disease of children; in rural Bangladesh attack rates are ten times greater in the one-to five-page group than in those above fourteen years of age. However, when the disease spreads to previously uninvolved areas, the attack rates are initially at least as high in adults as in children.

3.2.3 Bacillary Dysentery (Shigellosis)

Shigellosis is an acute bacterial disease, primarily of the large intestine, characterized by diarrhea, fever, nausea, and sometimes, cramps, vomiting, and tenesmus. Shigellosis is a serious disease with significant mortality, especially in infants and children.

3.2.3.1 Risk factors of shigellosis

There are four species in the genus: Shigelladysenteriae, S. ftexneri, S.oydii, and S. sonnei. S. dysenteriae Type 1 is the "shiga bacillus" of Kiyoshi Shiga, isolated during a severe epidemic in

Japan in 1897, associated with a mortality rate of 25 percent. S. dysenteriae virtually disappeared after 1920 until it returned in 1969 in Central America with an estimated 112,000 cases, with 8,300 deaths in the first 10 months in Guatemala alone (Gangarosa, et al.,1970)[11]. S. sonnei and S. flexneri are the most prominent forms, in that order, in the United States. The disease has always flourished under crowded conditions with poor sanitation.

3.2.3 Amebiasis

Although amebiasis means infection with amebas, the word is generally construed as meaning infection of the large intestine by Entainoebahistolytica because only this species of the six amebae that naturally parasitize the human intestine causes significant disease. However, Dientamoe bafragilis apparently can cause mild intestinal symptoms. Amebiasis is found worldwide, with perhaps 10 percent of the population infected. Prevalence in areas with poor hygiene and sanitation is much higher, often 30 percent, and within some developing countries as high as 83 percent.

3.2.3.1 Risk factors of Amebiasis

Man becomes infected with E. histolytica by swallowing the cysts (the only infective forms), which reach the mouth through fecally contaminated food, water, or other objects, e.g., fingers. Transmission is highest in areas of poor sanitation. Fecal contamination of water for drinking and food preparation; use of night soil as a fertilizer for vegetables eaten raw; lack of handwashing, especially by food handlers; and mechanical contamination of food by house-flies and roaches are possible sources of infection. General health and nutrition of the infected population are important factors in the severity of the disease. Also, strains of E. histolytica isolated in tropical areas are generally more virulent than those from temperate zones.

Role of water supply in transmission

Certain factors are relevant to understanding the role of water supply in transmission and prevention of amebiasis

(1) Amebiasis is manifested primarily in endemic form. The incubation period is variable, from a few days to several months or years, although most commonly 2 to 4 weeks. Thus epidemic "peaks" are relatively flat and often unrecognized in the community. Further, many people harboring E. histolytica do not develop the disease but may pass the cysts for years. Also multiple sources of infection are common.

(2) A water supply contaminated with E. histolytica can result in epidemic amebiasis.
The first recognized water-borne outbreak was in Chicago in 1933, where a crossconnection between a sewer and water supply for two hotels resulted in an outbreak with 1,409 cases with 98 deaths (Bundesen, 1936). Despite such spectacular outbreaks, the majority of cases probably stem from cumulative, chronic, contamination. Nevertheless, these outbreaks serve as a reminder of the need for surveillance of drinking water quality water.

(3) The cysts of E. histolytica can survive for weeks in water.

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[11] *Gangarosa, Eugene J., et al. "Epidemic Shiga Bacillus Dysentery in Cen-tral America. II. Epidemiologic Studies in 1969." The Journal of Infectious Diseases. 122(3): 181-190. 1970.*

(4) The cysts survive chlorination at normal levels. Filtration, preferably through diatomaceous earth, is required to ensure their removal.

(5) "Freshening" of raw vegetables by sprinkling with cyst-contaminated water can result in transmission.

(6) Hand washing following defecation is important. Standard public health interventions to improve hand hygiene in communities with high levels of child mortality encourage community residents to wash their hands with soap at five separate key times, a recommendation that would require mothers living in impoverished households to typically wash hands with soap more than ten times per day.

3.2.4 Giardiasis

Giardia enteritis is a protozoan (Giardia lainblia) infection of the upper small bowel. Often asymptomatic, it may present with chronic diarrhea, steatorrhea, abdominal cramps, frequent loose, pale, greasy, malodorous stools, fatigue, and weight loss.

3.2.4.1 Risk factors of Giardiasis

It occurs worldwide in areas of poor sanitation. Approximately Non-Cholera Vibrios 30 waterborne outbreaks, affecting over 10,000 persons, have been reported in the U.S. since 1970. Giardiasis is prevalent in the tropics, and children are infected more often than adults rates occur in children suffering from malnutrition Maximum
(Knight, 1978)[12]. Transmission is fecal-oral by water, food, and hand to mouth, with water a common source of outbreaks, partly because the usual concentrations of chlorine for water disinfection do not kill giardia cysts. Some evidence of animal contamination of water supplies also exists, particularly by beavers.

3.2.5 Typhoid Fever

Typhoid fever is by sustained fever, headache, anorexia, slow heartbeat, rose spots on the trunk, constipation more commonly than diarrhea, and on occasion, intestinal hemorrhage or perforation. The untreated fatality rate maybe 10 percent. Mild and inapparent cases occur, especially in endemic areas (Benenson, 1981) [13] . The infectious agent is Salmonella typhi, the typhoid bacillus. Occurring worldwide, the disease is spread by food or water contaminated by the feces or urine of a patient or carrier. Shellfish and milk are also important vehicles for transmission.

3.2.5.1 Typhoid situation in Pakistan

The risk of XDR S. Typhi at the national level is considered high in Pakistan due to insufficient water, poor sanitation, and hygiene (WASH) practices, low vaccination coverage, and limited surveillance for typhoid fever. The fact that AMR *S.* Typhi confirmatory testing and antimicrobial susceptibility testing is only conducted by major laboratories and tertiary care hospitals are other priority considerations in terms of risk. These factors, coupled with sub-optimal antibiotic prescribing practices, have limited the ability to track the occurrence, spread, and containment of XDR *S.*Typhi. Outbreaks of MDR typhoid and sporadic cases of infection with ceftriaxone-

[12] *Knight, R. "Giardiasis, Isoporiasis and Balantidiasis." Clinician Gastroenterology. 7(1):31-47. 1978.*
[13] *Benenson, Abram S., Editor. Control of Communicable Diseases in Man. 13th Edition. American Public Health Association, Washington. 443pp. 1981.*

resistant *S.* Typhi have been reported in several countries. However, this is the first time a large outbreak caused by XDR *S.* Typhi has been observed in Pakistan. The risk at the regional level is considered moderate due to similar environments and approaches to the treatment of typhoid fever, as well as the widespread over-use of anti-microbial, which is compounded by considerable levels of migration within the region[14].

3.2.5.2 WHO recommends the use of first typhoid conjugate vaccine

Using typhoid vaccines to control endemic and epidemic typhoid, and WHO recommends that typhoid-endemic countries introduce TCV in a single dose for infants and children over the age of six months. Where feasible, vaccine introduction should be accompanied by catch-up vaccination campaigns for children up to 15 years of age in endemic countries[15].

3.2.5.3 Risk factors of typhoid

Typhoid fever, unlike most another salmonellosis, strictly limited to man. The infection results from the ingestion of 3. typhi, experimentally in the range of 1,000 to 100,000 organisms. In nature the infectious dose is probably lower. The sources of infection are the sick, or more often, carriers who excrete S. Typhi in their stools or urine. The epidemiology of typhoid has been thoroughly studied. Numerous observations leave no doubt about the role of food and water (Cvjetanovic, 1973)[17]. Infection is often transmitted by contaminated water. Because S. typhi can survive in seawater, near sewage outlets are seafood, particularly, shellfish collected particularly dangerous.

3.2.6 Paratyphoid fever

Typhoid fever, but generally milder and with lower fatality rates. Mild and asymptomatic infections occur. Three main groups of infectious agents are recognized:

Salmonella paratyphi A

Salmonella paratyphi B (5.schottnueri) Salmonella paratyphi C (5. hirschfeldii) All of predominately human origin.

3.2.6.1 Risk factors of paratyphoid fever

Transmission is fecal-oral, by food or food handlers. Occasional outbreaks are related to water supplies, including swimming water. Preventive measures are similar to those for typhoid. However, standard vaccines are less effective.

3.2.7 Salmonellosis

Salmonellosis is an acute, infectious, bacterial disease with sudden onset of abdominal pain, diarrhea, nausea, fever, and sometimes vomiting. Fatality is low except among the young, the old, and the debilitated. Over 2,000 serotypes of Salmonella are pathogenic, with S.typhimurium the

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[14] *World Health Organization. Typhoid situation in Pakistan.. http://www.nih.org.pk/wp-content/uploads/2018/08/AMRNational-Action-Plan-Pakistan.pdf*

[15] *https://www.who.int/medicines/news/2017/WHOprequalifies-breakthrough-typhoid-vaccine/en/* [17] *Cvjetanovic . Fever and its prevention. Itation "Typhoi: anl. views. 11(3): 229-246. 1973.*

most common. Typhoid fever and paratyphoid fevers are salmonellosis but are discussed in a separate section. Salmonellosis is very much associated with animals as well as men**.**

3.2.7.1 Risk factors of Salmonellosis

Transmission is fecal-oral from person to person and via contaminated food or water. Epidemics are usually traced to food or milk. Fecal contamination of chlorinated public water supplies has been involved in some extensive outbreaks. Salmonellae are found worldwide. One of the most noteworthy waterborne outbreaks of water-borne salmonellosis was that at Riverside, California, in 1965 (Ross, Campbell, and Ongerth, 1966; Greenberg and Ongerth, 1966), which affected an estimated 18,000 people. This epidemic was attributed to S.tyr tnuritam.

3.2.8 Leptospirosis

Leptospirosis is a group of diseases caused by various serovars (formerly serotypes) of Leptospires e.g., L. icterohaemorrhagiae. Symptoms include fever, headache, chills, severe malaise, vomiting, myalgia, and others. Fatality is low except for cases with jaundice and kidney damage.

3.2.8.1 Risk factors of Leptospirosis

The pathogens are transmitted through skin contact with water, soil, or vegetation contaminated with the urine of infected rats or other hosts or occasionally through ingestion. Exposure is largely occupational with farm or fish workers or others who are frequently in contact with contaminated water or with infected animals and their urine. Recreational exposure is important with swimmers in contaminated water.

3.2.9 Tularemia

Tularemia is a congeries of syndromes" (Homick, 1980)[16] related to the route of introduction and the virulence of the pathogen, Francisella tularensis, zoonotic coccobacilli. When transmitted by ingestion, it may produce pharyngitis, intestinal pain, diarrhea, and vomiting. Most commonly the skin is the portal of entry, and the most common form is as an indolent, febrile disease with a skin ulcer and draining lymph nodes. Pneumonia, typhoid, and oculo glandular forms also occur.

3.2.9.1 Risk factors of Tularemia

Rarely transmitted from one person to another, it is most commonly acquired through the handling of the carcass or eating the undercooked flesh of infected animals. Rabbits are the most common animal victims.

3.2.10 Hepatitis A

Hepatitis A is a vaccine-preventable, communicable disease of the liver caused by the hepatitis A virus (HAV).

3.2.10.1 Risk factors of Hepatitis A

It is usually transmitted person-to-person by the fecal-oral route or through the consumption of contaminated food or water. Hepatitis A is a self-limited disease that does not result in chronic

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[16] *National Academy of Sciences. Drinking Water and Health. Vol. 3. Pp. I- 24. 1980.*

infection. Most adults with hepatitis A have symptoms, including fatigue, low appetite, stomach pain, nausea, and jaundice, which usually resolve within 2 months of infection; most children less than 6 years of age do not have symptoms or have an unrecognized infection. Antibodies produced in response to HAV infection last for life and protect against reinfection. The best way to prevent HAV infection is to get vaccinated**.**

3.3 Carcinogenic in Drinking Water

The increasing number of organic chemicals reaching water supplies in industrial areas has generated growing concern as to their carcinogenic potential in drinking water. Some compounds are known to be carcinogenic (in the test! of animals exposed to high doses) have been found in water supplies, albeit in low concentrations. One of these is chloroform, which can be a by-product of the chlorination process for water disinfection, a process practiced in the U.S. since 1908, which has undoubtedly prevented the great loss of life.

The question of the effect of potential carcinogens found in drinking water has been intensively studied by the National Academy of Sciences (NAS), which recently reported on chloroforms and other trihalomethanes (THMs) in drinking water. The NAS has summarized (1980)[17], based on its review of 12 epidemiological studies, that any association between THMs and bladder cancer "was small and had a large margin of error" and those inherent methodological complexities make it "virtually impossible to establish a causal link between THMs and an increase in cancer of the bladder or of any other site." This subject has also been recently reviewed by Wilkins, Reiches, and Kruse (1979) [20] , who found that "the association between organic chemical drinking water contaminants and cancer is not well confirmed," and "at present, the evidence of a few statistically significant results must be tempered by recognizing the large number of test statistics that have been computed, as well as their reported levels of significance." However, "even though strong drinking watercancer relationships have not emerged in these exploratory efforts, there still appears to be a justification for pursuing the drinking water question."

Pakistani study aimed at monitoring and risk assessment of trihalomethanes (THMs) such as chloroform, bromodichloromethane, dibromochloromethane, and bromoform, in the drinking water supplies of Rawalpindi and Islamabad. THMs were monitored at twenty locations in these twin cities using solid phase micro extraction-gas chromatography (SPME-GC). The total concentration of THMs was ranged between 21 and 373µg/L, whereas both cities had an average total THMs concentration of 142 and 260µg/L, respectively. Chloroform was found as one the major contributor to the THMs concentration (>85%). Lifetime cancer risk assessment of THMs was carried out using prediction models via different exposure routes (ingestion, inhalation, and dermal). An average lifetime cancer risk was found to be 0.74×10(-4) and 1.24×10(4) for Rawalpindi and Islamabad, respectively. The number of expected cancer cases per year could reach two cases for each city. Hazard index values were found below unity for both the cities implying that there would be no considerable non-cancer risk. Oral ingestion was found to be one of the main routes of exposure for both types of risk which was followed by inhalation and dermal routes[18].

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[17] *National Academy of Sciences. DrinkingWater and Heulth. Volume 3. Pp. 1-22. Washington. 1980. Schneiderman, Marvin A.* [20] *Wilkins, John R., Ill, Reiches, Nancy A., and Kruse, Cornelius W. "OrganicChemical Constituents in Drinking Water and Cancer." American Journalof Epidemiology. 110(4): 420-448. 1979.*

[18] *Ahmed H. Cancer and Non-Cancer Risk Assessment of Trihalomethanes in Urban Drinking Water Supplies of Pakistan. Ecotoxicol Enviro Saf 2013.*

3.4 Diseases Associated with Swimming

Surprisingly, perhaps, bathers can swim in waters that are heavily sewage-laden and not contract diseases, apparently be-cause little of the water is ingested. Sewage-laden water is a potential source of organisms that cause enteric disease (Cabelli, 1978, 1979)[19]. Mailman (1970) lists numerous typhoid outbreaks associated with swimming in fresh and seawaters. Swimming pools present a somewhat different settingpollution is limited to those organisms discharged from the body of the swimmer, dilution is limited, and disinfection with chlorine is the usual practice. Inflammations of the ear (otitis), sinuses (sinusitis), eye (conjunctivitis), and skin (dermatitis) are not uncommon. Skin infection of abrasions, usually on knees and elbows, known as "swimming pool granuloma" also is found among pool users (and occupationally as well). It is caused by Mycobacterium balnei (Feldman, 1974) [23.] A mild viral infection, of the nose, throat, and eyes are known as pharyngoconjunctival fever is also associated with swimming pools. "Swimmers' itch," also called schistosome dermatitis, is found in swimmers and waders in several areas. This is Avian schistosomiasis in which cercariae attack the skin of man but are unsuccessful in establishing themselves. The itch is an allergic reaction. Most skin infections of swimmers are mild and heal rapidly (Hicks, 1977)[20].

3.5 Public Health effects of water treatment

The diarrheal disease nearly 90% of which has been attributed to suboptimal water, hygiene, and sanitation (WASH) is one of the largest causes of morbidity and mortality in children under five years of age in low and middle-income countries. Drinking water sources are subject to contamination and require appropriate treatment to remove disease-causing agents. Public drinking water systems use various methods of water treatment to provide safe drinking water for their communities. Water may be treated differently in different communities depending on the quality of the water that enters the treatment plant. Typically, surface water requires more treatment and filtration than groundwater because lakes, rivers, and streams contain more sediment and pollutants and are more likely to be contaminated than groundwater[21].

3.6 Mechanisms for Reducing Health Risks Through water Treatment

Following different steps are adopted by the MC Jacobabad to provide safe drinking water and effectively prevent water-borne diseases among the population.

3.6.1 Physical Removal

This is an important method of physical removal of large particles and undesirable constituent without significantly changing its character. For example, sedimentation or filtration may remove bacteria and viruses from water efficiently without influencing the viability of the organisms. Slow sand filtration has been reported to remove 85-99% of bacterial pathogens from water. This can be attributed to the effectiveness of the filtration process in removing suspended matter, including bacteria, and to a natural die-off of those bacteria during storage in the filter under conditions

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[19] *Cabelli. Victor J., et at. "Relationship of Microbial Indicators to Health Effects at Marine Bathin, Beaches." American Journalof PublicHealth. 69(7): 690-696. 1979.* [23] *Feldman, Roger A."Primary Mycobacterial Skin Infection: ASummary." .nternationalJournal of Dermatology. 13(6): 353-356. 1974.*

[20] *Hicks, John H. "Swimming and the Skin." Cutis. 19: 448-50. 1977.*

[21] *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4580573/*

environmentally unfavorable to their survival (Wagner, 1959)[22]. Higher efficiencies usually can be attained in properly operated rapid sand filter plants.

Coagulation and settling are capable of removals in the range of 95-99% of the bacteria. When followed by rapid sand filters, overall removals well more than 99% should be readily attainable in a properly operated plant.

3.6.2 Pretreatment to Enhance Removal

In this process constituents separated after pretreatment to facilitate the removal process. For example, heavy metals often are removed through precipitation to convert the soluble ions to insoluble forms, followed by settling and, perhaps, filtration. Removal of bacteria and viruses may be improved substantially by coagulation to agglomerate them into larger particles before settling. Removal of iron and manganese may be enhanced by aeration or chlorination to oxidize the metal to a higher valence state, facilitating its precipitation and removal by subsequent settling and filtration. This process is installed at different distances before the treatment plant.

3.6.3 Disinfection

Extensive removal of bacteria by various water treatment processes notwithstanding, disinfection remains the principal line of defense against the transmission of waterborne diseases. Even removals well over 99.9% of coliform organisms from typical surface waters usually will be inadequate to ensure safety from waterborne diseases as represented by commonly accepted drinking water standards. Accordingly, the production of a finished product consistent with those standards almost always depends heavily upon effective disinfection. Slow sand filtration, or coagulation, settling and rapid sand filtration, followed by disinfection of the treated water can virtually assure freedom from significant risks of transmitting communicable diseases via the drinking water route.

This is an important consideration in designing, constructing, and operating a water treatment plant is a reduction in the risk of transmitting pathogenic bacteria to the public. Bacteriological quality of water is assessed through enumerating coliform bacteria. That also permits evaluation of the effectiveness of the treatment system in reducing the risk of transmitting waterborne diseases, whether or not pathogens happen to be present at the time of measurement.

3.6.4 Secondary Effects

This treatment occupies a role, which may be secondary, but important, in determining the efficiency of disinfection. It has been observed that the disinfection of turbid waters may be difficult to accomplish efficiently because some organisms are shielded within turbidity particles, blocking contact between them and the chlorine compounds. Subsequently, they may be separated from the turbidity particles and remain viable in the water after the chlorine has been dissipated. Accordingly, removal of turbidity is considered to be an important facet of water treatment for the destruction of pathogenic bacteria and viruses, even though the turbidity itself has no direct role in disease transmission.

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[22] *Wagner, E.G., and Lanoix, J.N. Water Supply for Rural Areas and Small Communities. World Health Organization, Geneva. 1959.*

3.6.5 Role of water supply from filter Plant to Distribution System in Jacobabad

The water filtration plant acts as the linchpin in the water supply system where the cleansing and monitoring of the water being supplied is happening. The project personnel stationed at the water filter plant will be to coordinate and work with the Municipality staff and provide on the job training for the maintenance of the system.

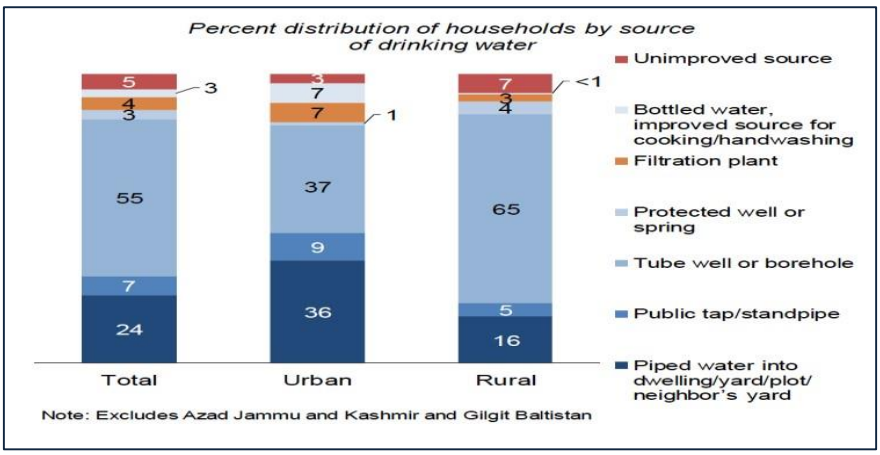
- The duty of the Engineer working on distribution system will be to ensure the water quantity and quality at the source (i.e. filter plant) and the rate of inflow (water received from high lift pumping station) and outflow from filter plant is nearly same so that the supply of water through pumping should not be disturbed during pumping to the overhead reservoir (OH).
- The O.H reservoirs are field as per the schedule of supply and quantity of inflow and outflow must be checked for keeping the level of O.H reservoir constant. This will assist in maintaining the lead and pressure in the tail-end areas of the supply.
- Water supply hours through each reservoir are set according to the population of the area. The area sub engineer/valve man operates valves to provide water in each Mohalla ensuring the pressure in the tail end residential units
- The schedule of water supply, filling time of O.H reservoirs of different zones, the quantity of water supply through each O.H reservoir as per population, timing of the supply would be prepared with consultation of field staff and public representative as per availability of water from the source.
- The distribution network is recently laid hence there are fewer chances of leakages and contamination but if due to illegal connection or due to any leakage sewage/subsoil water is mixed with supplied water, it is very essential to tress the defective part of the distribution line or fitting for immediate removal of contamination.

The procedure for detecting leakages, removal of contamination due to faulty connections, or any other reason, the detailed procedure will be provided in operation and maintenance manual. Further, the following areas will also be considered during the on-job training of the MC staff.

3.6.6 Evidence of improved sources of drinking water

These include piped water, public taps, standpipes, tube wells, boreholes, protected dug wells and springs, and rainwater. Households that use bottled water for drinking are classified as using an improved source only if their water source for cooking and hand washing comes from an improved source. The most common source of drinking water in Pakistan is a tube well or borehole (55%), followed by piped water (24%). Tube wells or boreholes are the most common source in both urban and rural areas (37% and 65%, respectively). Seventy-three percent of households have drinking water on their premises, and 10% of households spend more than 30 minutes to obtain water. Eighty-seven percent of households using piped water or water from a tube well or borehole reported that water was available without interruption in the past 2 weeks (Figure 2).

Figure 2: Household drinking water by residence (PDHS 2017-18



3.7 Waterborne diseases faced by the people of Jacobabad city- Hospital Data

PDHS survey shows that safe drinking water could prevent water-borne infections like Hepatitis A & E around 17% in urban and 14% in rural Sindh. Waterborne diseases are caused by infected or contaminated water. Every year about 3.4 million people died by water-related diseases worldwide. Jacobabad is the underdeveloped city of Sindh province, having a population of more than a quarter of million (275,000 est.) and situated at the borders between Sindh and Baluchistan. The city has been derived from the basic need for safe drinking water and people are using dirty, polluted, adulterated, and infected water which is injurious for health. This phenomenon has become a major cause of waterborne diseases, which people of Jacobabad are facing day by day. Considering such an alarming situation study[23] was conducted in a civil hospital, Jacobabad in 2016 among 439 patients who visited the hospital. The main six waterborne diseases were observed likewise,

1. Hepatitis A (38%),
2. Typhoid (26%),
3. Diarrhea (16%),
4. Cholera (9%),
5. Dysentery (8%)
6. Dracunculiasis (3%)

From the above-collected cases, females were in preponderance with 58.1% and males with 41.9%. The highest ratio of patients belonged to the age group of 21 to 30 years. The majority of the people were using water supplied by Donkey cart vendors which are highly polluted. Waterborne diseases can be controlled if water will be purified and safe for biotic life.

3.7.1 Waterborne disease affecting age group in Jacobabad

People of Jacobabad city mainly used water from canals like Jamali Wah and Khirthar, piped water, borehole water, tube well water, Donkey cart vendor's water for drinking, and mineral water. So bacteria, viruses, and protozoans mostly contaminate the water. Many people are facing these diseases considering all age groups. In present findings people of all ages were

[23] *An Empirical Study on Waterborne Diseases Faced by the People of Jacobabad City 2017.*

suffering from waterborne diseases but the highest ratio was observed in the age group of 21-30 years, the second-highest ratio was found in 11-20 years of age group[24].

3.7.2 Waterborne disease affecting location in Jacobabad

The highest prevalence of diseases was found in residents of UC6 Mochi Basti with 24.7% which mentions that the water of Mochi Basti is so much polluted and adulterated. People also mentioned in Pro-forma that they are using water supplied by donkey cart vendors for drinking and cooking.

Drinking water of Jacobabad city is fully contaminated by feces (bacteria, viruses, and protozoans) that produce waterborne diseases like Hepatitis A, Guinea Worm disease, Diarrhea, Cholera, Typhoid, and Dysentery. These diseases could affect people at any age and found more among the residents of Mochi Basti (UC6), where the number of females was more as compared to males. Most of the people living in Jacobabad city belong to the lower and lower-middle class and they cannot afford mineral or purified water for their drinking so if safe and pure water will be provided to the city, these waterborne diseases can be controlled easily and people can have a healthier life.

[24] *An Empirical Study on Waterborne Diseases Faced by the People of Jacobabad City 2017.*